

Oregon Agricultural College Experiment Station

The Strawberry Root-weevils and Their Control in Oregon

By

DON C. MOTE and JOSEPH WILCOX



CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

BOARD OF REGENTS OF THE OREGON AGRICULTURAL COLLEGE AND EXPERIMENT STATION

HON. J. K. WEATHERFORD, President.....	Albany
HON. E. E. WILSON, Secretary.....	Corvallis
HON. B. F. IRVINE, Treasurer.....	Portland
HON. I. L. PATTERSON, Governor.....	Salem
HON. SAM A. KOZER, Secretary of State.....	Salem
HON. C. A. HOWARD, Superintendent of Public Instruction.....	Salem
HON. GEORGE A. PALMITER, Master of State Grange.....	Hood River
HON. MRS. W. S. KINNEY.....	Astoria
HON. SAM H. BROWN.....	Gervais
HON. HARRY BAILEY.....	Lakeview
HON. GEO. M. CORNWALL.....	Portland
HON. E. B. ALDRICH.....	Pendleton
HON. JEFFERSON MYERS.....	Portland

STATION STAFF

W. J. KERR, D.Sc., LL.D.....	President
J. T. JARDINE, B.S.....	Director
E. T. REED, B.S., A.B.....	Editor
H. P. BARSS, A.B., S.M.....	Plant Pathologist
F. D. BAILEY, M.S., Asst. Pathologist, Insecticide and Fungicide Bd., U. S. Dept. of Agri.	
B. B. BAYLES.....	Junior Agronomist, Office of Cer. Inves., U. S. Dept. of Agri.
R. S. BESSE, M.S.....	Associate in Farm Management
P. M. BRANDT, B.S., A.M.....	Dairy Husbandman
A. G. BOUQUET, B.S.....	Horticulturist (Vegetable Gardening)
E. N. BRESSMAN, B.S.....	Associate Agronomist
G. G. BROWN, B.S.....	Horticulturist, Hood River Br. Exp. Station, Hood River
W. S. BROWN, A.B., M.S.....	Horticulturist in Charge
D. E. BULLIS, B.S.....	Assistant Chemist
A. S. BURRIER, M.S.....	Assistant in Farm Management
LEROY CHILDS, A.B.....	Supt. Hood River Branch Exp. Station, Hood River
G. V. COPSON, M.S.....	Bacteriologist
H. K. DEAN, B.S.....	Supt. Umatilla Branch Exp. Station, Hermiston
C. R. DONHAM, D.V.M.....	Assistant Veterinarian
THEO. P. DYKSTRA, M.S.....	Assistant Plant Pathologist, U. S. Dept. of Agri.
E. M. EDWARDS, B.S.....	Asst. Animal Husbandman, East Ore. Br. Exp. Sta., Union
A. E. ENGBRETSON, B.S.....	Supt. John Jacob Astor Br. Exp. Station, Astoria
L. N. GOODING, B.A., B.S.....	Jr. Plant Pathologist, U. S. Dept. of Agri.
W. V. HALVERSEN, Ph.D.....	Associate Bacteriologist
H. HARTMAN, M.S.....	Associate Horticulturist (Pomology)
E. M. HARVEY, Ph.D.....	Horticulturist (Physiology)
BERTHA C. HITE, B.A., Scientific Assistant Seed Lab., U. S. Dept. of Agri. (Seed Analyst)	
R. E. HUTCHINSON, B.S.....	Asst. to Supt. of Harney Valley Branch Exp. Station, Burns
G. R. HYSLOP, B. S.....	Agronomist
W. T. JOHNSON, D.V.M.....	Poultry Pathologist
I. R. JONES, Ph.D.....	Associate Dairy Husbandman
J. S. JONES, M.S.....	Chemist
G. W. KABLE, M.S.....	Agricultural Engineer
F. L. KNOWLTON, B.S.....	Poultry Husbandman
A. G. LUNN, B.S.....	Poultry Husbandman in Charge
M. B. MCKAY, M.S.....	Plant Pathologist
H. G. MILLER, Ph.D.....	Chemist
G. A. MITCHELL, B.S.....	Asst. to Supt. of Sherman County Branch Exp. Station, Moro
DON C. MOTE, M.S.....	Entomologist
O. M. NELSON, B.S.....	Animal Husbandman
R. K. NORRIS, B.S.....	Assistant to Supt. of Southern Oregon Branch Exp. Station, Talent
A. W. OLIVER, B.S.....	Assistant Animal Husbandman
E. L. POTTER, M.S.....	Animal Husbandman
W. L. POWERS, M.S.....	Chief, Department of Soils
F. C. REIMER, M.S.....	Supt. Southern Oregon Br. Exp. Station, Talent
R. H. ROBINSON, A.B., M.S.....	Chemist
C. C. RUTH, M.S.....	Associate Agronomist
C. V. RUZEK, B.S.....	Associate in Soils (Fertility)
H. A. SCHOOT, M.S., Asst. Agronomist, Forage Crops Investigation, U. S. Dept. of Agri.	
C. E. SCHUSTER, M.S.....	Associate Horticulturist (Pomology)
H. D. SCUDDER, B.S.....	Chief in Farm Management
H. E. SELBY, B.S.....	Associate in Farm Management
O. SHATTUCK, M.S.....	Supt. Harney Valley Branch Exp. Station, Burns
J. N. SHAW, D.V.M.....	Assistant Veterinarian
J. E. SIMMONS, M.S.....	Assistant Bacteriologist
B. T. SIMMS, D.V.M.....	Veterinarian
D. E. STEPHENS, B.S.....	Supt. Sherman County Br. Exp. Station, Moro
R. E. STEPHENSON, Ph.D.....	Associate Soils Specialist
B. G. THOMPSON, M.S.....	Assistant Entomologist
E. F. TORGERSOON, B.S.....	Assistant in Soils (Soil Survey)
E. H. WIEGAND, B.S.....	Horticulturist (Horticultural Products)
JOSEPH WILCOX, B.S.....	Assistant in Entomology
MAUD WILSON, B.S.....	Home Economist
ROBT. WITHYCOMBE, B.S.....	Supt. Eastern Ore. Branch Exp. Station, Union
W. W. YATES, B.S.....	Assistant Chemist
S. M. ZELLER, Ph.D.....	Plant Pathologist

CONTENTS

	Pages
Introduction	5
Injury	6-7
Distribution in Oregon	7
Host Plants	8
Experiments with Apple Baits	8-17
Preparation of Home-made Bait	9-10
What Poison to Use	10-13
Amount of Poison to Use	13
Percent of Moisture in Bait	13
The Commercial Bait "Go-West"	14
Time and Number of Applications of Bait	14-15
Method of Application	15-17
Experiments with Bran Baits	17-18
Experiments with Dusts	19
Life-history and Habits of the Weevils	19-22
Cultural Measures as an Aid in Control	22
Acknowledgments	22
Summary	22-23
Literature Cited	24

CONTROL OF THE STRAWBERRY ROOT-WEEVILS

Experiments made during the 1926 season have shown that:

A home-made bait made of 95 pounds of ground dried apple mixed with 5 pounds of powdered poison and the commercial bait Go-West will kill the adults of the Strawberry Root-Weevils.

Calcium arsenate is the most effective poison and is the poison recommended to use in the home-made baits.

The bait is best applied at the rate of from a teaspoonful to a tablespoonful to a hill directly in the crown of the plant.

The time to make the first application of the bait is when about 75 percent of the weevils have changed to the adult stage.

Applications of the bait at this time will kill the weevils before they lay their eggs.

The Strawberry Root-weevils and Their Control in Oregon

By

DON C. MOTE and JOSEPH WILCOX

INTRODUCTION

The Strawberry Root-Weevils constitute one of the worst menaces to the strawberry industry in Oregon. Strawberry patches heavily infested by these insects are either destroyed in two or three years or else the yield in berries is so reduced that the patch becomes unprofitable. Four species of weevils have been found feeding on and destroying the roots and crown of strawberry plants in Oregon. These are the Small or Common Strawberry Root-Weevil,* the Medium-sized Strawberry Root-Weevil†, the Large Strawberry Root-Weevil‡, or the Black Vine Weevil, and a new species§ of weevil that was found in 1926.

Until the announcement in 1925 of a commercial strawberry weevil bait and the publication of the bulletin in 1926 by Melander and Spuler¹ on poison apple baits, little or no success had attended the attempts to control these insects. As these experiments and recommendations are based entirely on work done in the state of Washington it was deemed advisable to make additional studies of the life-history and habits of the weevils in Oregon and to conduct experimental tests with the commercial and home-made baits under Oregon conditions. This investigation was undertaken as a Purnell project in the spring of 1926. The work was conducted in both the Willamette and Hood River valleys, not only because the weevils have been most destructive in these two valleys but because these districts offer a wide variation of weather conditions under which to study the weevils.

The material embodied in this circular is taken mainly from the studies conducted in the Willamette Valley and is supplemented with the information obtained in the Hood River Valley. The results as presented are not complete or conclusive at the present date. They are published at this time to meet the numerous requests for information on the Strawberry Root-Weevils that are being received and to present to the growers some of the factors that must be considered if the bait applications are successful. With this information at hand it is believed that the growers can proceed with the control of the weevils with a greater degree of accuracy than they did the past season.

**Brachyrhinus ovatus* L. Hereafter termed in the text the Small Strawberry Root-Weevil or the Small Weevil.

†*Brachyrhinus rugifrons* Gyll. Hereafter termed the Medium-sized Strawberry Root-Weevil or the Medium-sized Weevil.

‡*Brachyrhinus sulcatus* Fab. Hereafter termed the Large Strawberry Root-Weevil or the Large Weevil.

§The fourth species of Strawberry Root-Weevil, discovered in the Woodburn district in 1926, shows promise of being as destructive as the other species of weevils. Specimens of this weevil sent to Dr. E. C. Van Dyke of the University of California were determined as *Dyslobus granicollis* Lec. According to Dr. Van Dyke this insect is a native of the Pacific Northwest and is commonly collected on salmonberry, hazel, and other plants found in the bottom-lands. This weevil is not discussed in this circular as but little is known of its life-history and habits and no experiments for its control have been conducted. It should not be confused with the other species of weevil as it does not change over to the adult stage until in August and September and passes the winter as adults in the ground about the roots of the plants.

INJURY

The appearance of a field infested by weevils is characterized mainly by distinct areas, usually circular, in which the plants are stunted. These spots vary in size from $\frac{1}{20}$ to $\frac{1}{2}$ acre. This peculiar spotted infestation can best be explained by the fact that the weevils usually gain entrance to the fields by crawling, and being somewhat gregarious, naturally collect in groups. The plants in this area are stunted at the end of the



Fig. 1. View of strawberry field showing healthy three-year-old Wilson plants.

first year so that the adult weevils move out to more healthy plants to lay their eggs. This instinct on the part of the weevils to seek out healthy plants is quite pronounced.

The injury by the Strawberry Root-Weevils is mainly that caused by the feeding of the larvae on the small fibrous roots of the plant. This results in a stunting and usually the death of the plant. In some cases the weevil grubs are found feeding on the outside of the crown of the plants and even in a few cases bore into the crown. Such grubs are usually a pinkish color.

The Strawberry Root-Weevils are not to be confused with the Strawberry Crown Moth,* more commonly called the "Strawberry Crown Borer" in Oregon. The larva of the crown borer is from $\frac{3}{4}$ inch to one inch long when full grown, has three distinct pairs of legs, and is found only inside the crown of the plant. Also, the weevils should not be confused with the Strawberry Crown-Miner,† the larva of which is a

**Synanthedon rutilans* Hy. Edw.

†*Aristotelia fragariella* Busck.

small, active, slender, pinkish-red worm about $\frac{3}{8}$ inch long and which is found only inside the crown of the plant. The adults of the Crown Borer and Crown-Miner are moths, while the adults of the weevils are small, dark-brown beetles. The larvae or grubs of the weevil are legless and are found in the soil about the roots of the plant.

The adult weevils feed on the leaves at the edges, ragging them in a characteristic manner. This injury is not serious, however.



Fig. 2. View of same field in practically the same rows showing the results of weevil injury on the plants.

DISTRIBUTION IN OREGON

The distribution of the Strawberry Root-Weevils in Oregon now includes practically all of the commercial berry producing sections of the state. The weevils are well established in Multnomah, Washington, Clackamas, Marion, Linn, Hood River, Wasco, Umatilla, Yamhill, Columbia, Polk, and Coos counties. Counties from which they have been reported are Douglas, Jackson, Benton, Lincoln, Tillamook, Lane, and Clatsop.

The Medium-Sized Weevil is at present confined to the Willamette Valley and can be found in more or less scattered plantings from Lane to Multnomah counties.

The Large Weevil occurs mainly in the lower Willamette Valley in Clackamas, Multnomah, Yamhill, Washington, and Columbia counties; in Hood River county and in Umatilla county.

The Small Weevil occurs in all the places where the other species are found and in addition in the other counties mentioned in the first paragraph.

HOST PLANTS

The cultivated strawberry is the preferred host plant of the Strawberry Root-Weevils. These pests, however, can exist and multiply on a number of plants, the most important ones of which are mentioned below.^{2, 3, 4} This list was compiled for the Small Weevil but the other species are as varied in their food habits.

- | | |
|--|---|
| 1. Strawberry | 8. Timothy |
| 2. Blackberry | 9. Blue-grass |
| 3. Raspberry | 10. Cinquefoil (<i>Potentilla glandulosa</i>) |
| 4. Loganberry | 11. Fowl meadow-grass (<i>Poa palustris</i>) |
| 5. Cranberry | 12. White clover |
| 6. Wild strawberry | 13. June grass (<i>Poa pratensis</i>) |
| 7. Sorrell (<i>Rumex acetosella</i>) | 14. Quack grass (<i>Agropyron repens</i>) |

The host plants on which the adult weevils will feed are quite numerous, and in addition to the above, close to 60 plants have been listed for the Small Weevil.

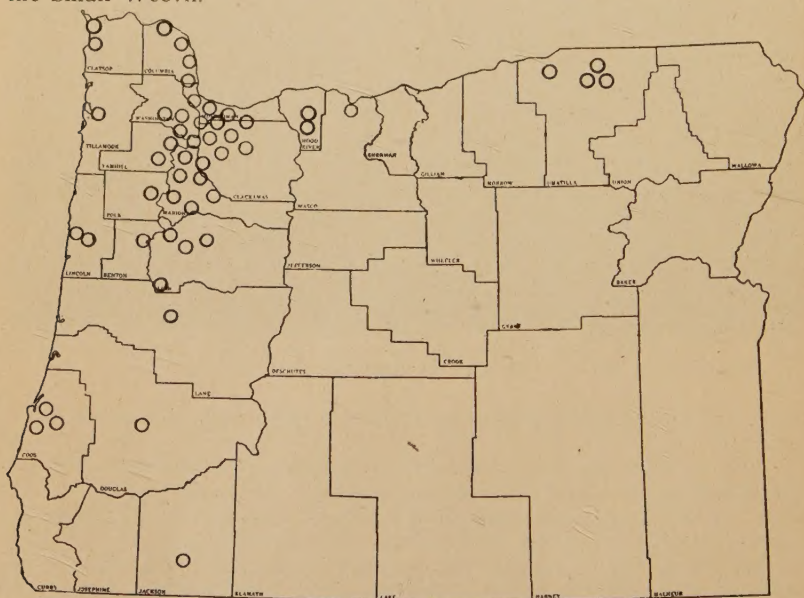


Fig. 3. Map of Oregon showing areas from which the Strawberry Root-Weevils have been reported.

EXPERIMENTS WITH APPLE BAITS

The Strawberry Root-Weevils, as stated in the introductory paragraph, have long defied the attempts of entomologists and others who have tried to control them. The discovery then, that the weevils will eat a bait made of ground apples mixed with poison, deserves considerable merit. This discovery is credited to M. J. Forsell, formerly fruit inspector of Snohomish county, Washington, and who at the present time

is manufacturing a commercial bait which is sold under the trade name "Go-West."

The discussion that follows is a summary of the field and laboratory tests made with home-made baits and with the commercial bait Go-West during the season of 1926 in the Willamette Valley and at the Experiment Station in Corvallis. The tests made in the field were mainly on two plantings in the Woodburn district and on a planting in the Shaw district; 1500 pounds of home-made bait and 1200 pounds of Go-West were applied. Seventy-four different field tests were made in which more than 16,000 weevils were counted. Experiments were also conducted relative to the time of application, manner of mixing and applying the home-made baits.

PREPARATION OF THE HOME-MADE APPLE BAIT

Dried apple peelings together with the cores, termed pomace or apple waste, containing 17 percent moisture were used in most of the tests with home-made baits. This material was ground through either a hand or a power meat grinder fitted with the coarsest grinders obtainable.

The grower, if he desires, may obtain the fresh peelings from the cannery and have them dried in a prune drier, or he may dry them in the sun or in the oven. If peelings are not available, cull apples may be used; they are cut in slices $\frac{3}{16}$ inch thick and dried. The material when dried may be sacked and held over winter with safety. As the bait after being mixed and sacked any length of time has a tendency to cake, it would be best to grind and mix the poison with the apples as near the time of applying as possible. This procedure is not imperative, however, as the lumps are easily broken with the hand while applying the bait in the field.

Grinding. It developed in our tests that sprinkling water on the peelings just before grinding makes them go through the grinder more quickly than if dry. One man can grind between 25 and 50 pounds of apple waste through a hand machine in an hour, and between 150 and 200 pounds can be run through a power meat grinder in an hour if the peelings are moistened before grinding. Grinding may not be a problem next year as one cannery plans to furnish the material already ground.

Mixing. The mixing of the poison with the apple waste is quite simple. For small quantities of bait the ground apple peelings are placed in a bucket or similar container and the correct amount of powdered calcium arsenate poured on top of the material. From two to four minutes stirring with a stick will insure a thorough mixing of the poison with the apple waste, the powdered poison adhering readily to the moist particles. Care should be taken not to breathe any of the poison dust in this mixing process. Where possible the mixing should be done in the open air.

For mixing larger quantities of bait, an O. A. C. diagonal axle dusting machine* made by Mr. H. F. Butterfield of Woodburn, for mixing

*More complete directions for making this mixing machine are given in Oregon Agricultural College Extension Bulletin 381, The O. A. C. Diagonal Axle Dusting Machine for Treating Wheat for Smut.

copper carbonate with wheat, was found to be very satisfactory. This machine is made from a 50-gallon steel drum fitted with a semi-circular, hinged door at one end for filling and emptying the drum and is rotated on a shaft running diagonally through it lengthwise. The drum is mounted on sawhorses and is turned by hand with a crank. It is estimated that the material and labor necessary to make such a machine would cost between \$8.00 and \$10.00.

By rotating the drum at a speed of 35 revolutions per minute, it was found that $1\frac{1}{2}$ minutes rotation would thoroughly mix the bait. In all the tests 50 pounds of bait were mixed at a time, but 75 pounds can easily be handled in this sized machine. With this machine two men in the course of one hour's time weighed out the poison and apple waste, and thoroughly mixed and sacked 300 pounds of bait.

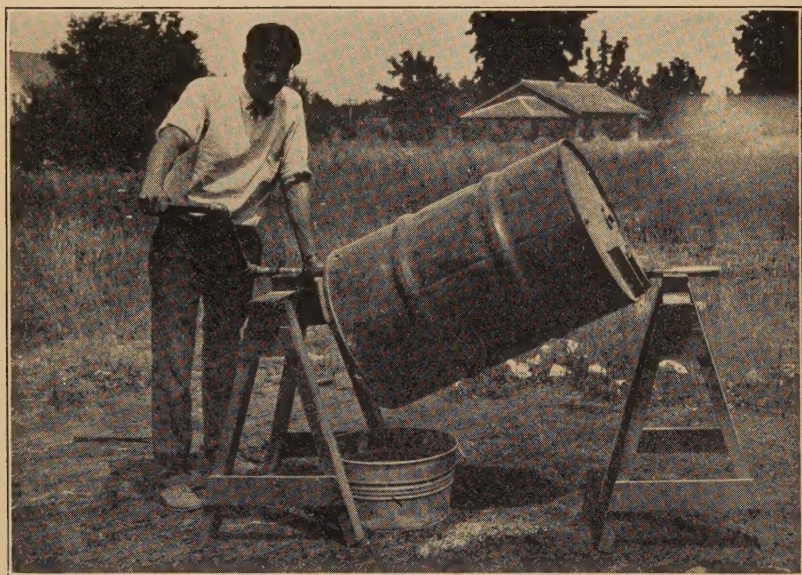


Fig. 4. Machine used in mixing ground dried apples with poison.

WHAT POISON TO USE

Rather extensive field and laboratory tests were conducted in order to ascertain which poison would give the best results under various conditions and at various times of application. Two of the plantings on which these tests were made were infested by the Small Strawberry Root-Weevil and the third was infested by the Medium-Sized Weevil. Since it is not deemed advisable in this preliminary report to go into each of these experiments separately, the averages of all have been taken. Table I gives a numerical summary of the field tests with home-made baits containing 5 percent poison, and the tests with the commercial bait Go-West. Fig. 5 gives graphically the data of Table I of the seven most efficient baits in our tests. The first application of bait re-

TABLE I. SUMMARY OF EXPERIMENTS WITH APPLE POISON BAITS CONTAINING 5 PERCENT POISON AND OF THE COMMERCIAL BAIT GO-WEST

No.	Poison or bait	No. of tests	Number and percentage of dead weevils at end of various periods after baiting														
			1 day			3 days			8 days			15 days			22 days		
			No. live	No. dead	Per- cent dead	No. live	No. dead	Per- cent dead	%	No. live	No. dead	Per- cent dead	%	No. live	No. dead	Per- cent dead	%
1	Calcium arsenate.....	8	415	77	84.35	27	768	27	96.60	765	11	98.58	62	0	100	100	
2	Lead arsenate.....	3	153	16	90.53	8	224	8	96.55	326	23	93.40	75	0	100	.....	
3	Zinc arsenite.....	4	179	18	90.86	180	12	93.78	195	14	93.30	68	0	100	.....		
4	Magnesium arsenate....	3	.....	.....	.....	59	9	86.76	120	4	96.77	54	0	100	.....		
5	Sodium fluosilicate.....	2	164	57	74.25	216	14	93.91	245	13	94.96	63	0	100	.....		
6	Go West.....	5	172	144	54.43	424	89	82.65	474	69	87.31	98	10	90.74	79	2	
7	Sodium fluoride.....	4	262	195	57.33	289	153	65.43	225	58	79.54	81	0	100	76	0	
8	Calcium fluoride.....	1	.....	.....	.....	.....	.....	34	7	82.92	.....	.....	.....	.....	.....	.....	
9	Paris green.....	2	.....	.....	.....	.....	.....	91	19	82.72	50	18	73.52	.....	.....	.....	
10	Calcium fluosilicate*..	1	7	97	6.73	11	113	8.87	29	94	23.57	.....	.....	.....	.....	.....	
11	Copper carbonate.....	1	2	71	2.73	.....	.....	12	76	13.43	.....	.....	.....	.....	.....	.....	
X	Check—no treatment..	12	1	331	00.30	9	386	2.27	4	180	2.17	3	67	.....	0	70	
																00.00	

*Commercial dust used containing only about 20 percent actual calcium fluosilicate. †4 days refers to magnesium arsenate only.

TABLE II. EXPERIMENTS WITH APPLE BAITS CONTAINING 5 PERCENT POISON COMPARED WITH BAITS CONTAINING A LESS PERCENTAGE OF POISON

Bait used	Count and percentage of dead weevils at end of various periods					22 days				
	1 day		3 days		8 days		15 days		No. dead	
	No. dead	No. live	Per cent dead	No. dead	Per cent live	No. dead	Per cent dead	No. dead	Per cent live	No. dead
	%		%		%		%		%	
Sodium fluoride 5%.....	38	24	61.29	62	8	88.57	.....	.....	76	0
Sodium fluoride 2%.....	173	12	93.51	50	28	64.10	186	1	73	1
Calcium arsenate 5%.....	103	35	74.63	215	8	96.41	102	2	.....	.....
Calcium arsenate 2½%.....	164	57	74.25	216	5	97.75	245	13	98.07	2
Sodium fluosilicate 5%.....	113	38	74.83	126	14	93.91	245	13	94.96	.....
Sodium fluosilicate 2½%.....	1	331	00.30	9	44	74.11	43	22	66.15	.....
Check.....	.....	.....	.....	.....	386	2.27	4	180	2.17	0

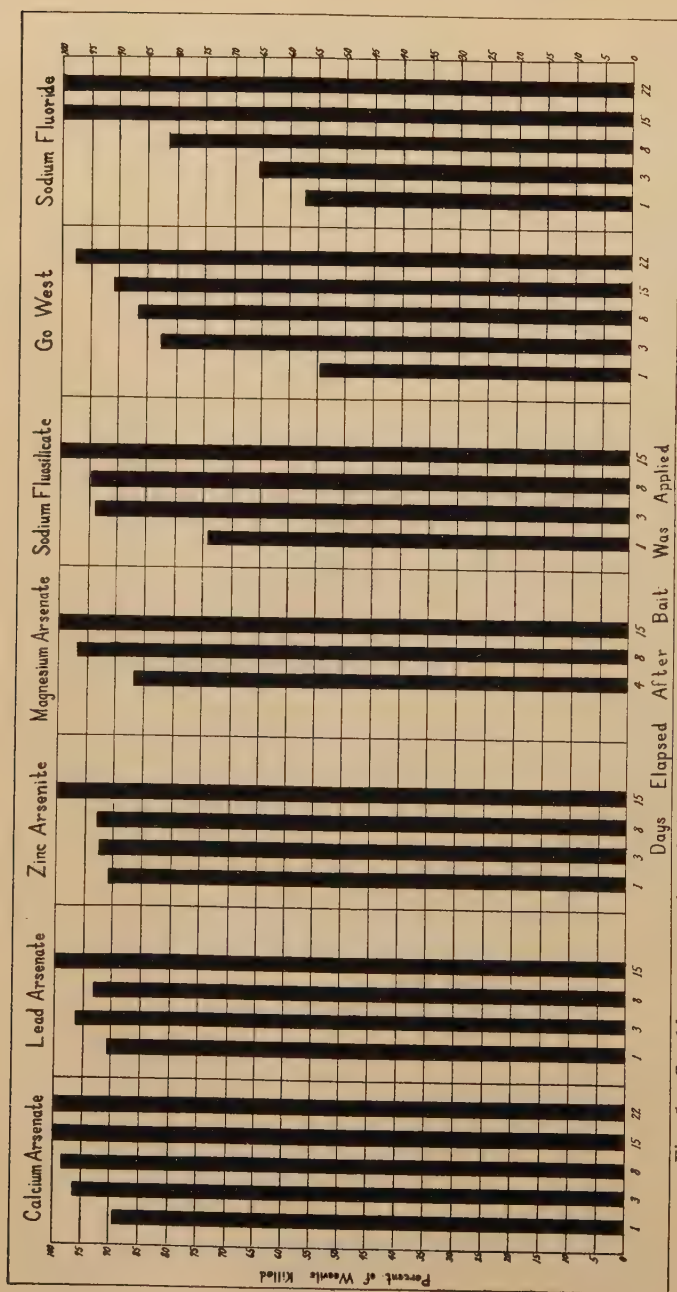


Fig. 5. Graphic representation of the seven most effective apple baits in our tests. For figures see Table I.

ported in these tests was made May 13 and the last application July 5. In a summary of this type certain discrepancies appear because of the various conditions under which the baits were applied. From the summary, however, it is apparent that **calcium arsenate** gave the best results. Until additional experiments are carried out calcium arsenate is the poison recommended to use in the home-made baits.

AMOUNT OF POISON TO USE

In preliminary experiments it was determined that 5 parts of poison to 95 parts of ground apple by weight, or 5 percent poison, would thoroughly cover all particles of the ground apple. More poison than this would not stick to the particles and was therefore wasted. Experiments were also conducted in which less amounts of poison were used. The results of these experiments were quite varied as can be seen from Table II. Calcium arsenate, $2\frac{1}{2}$ percent, gave comparatively good results but as the other poisons did not compare so favorably it is not deemed advisable to use less than 5 percent poison until further experiments have been conducted.

PERCENT OF MOISTURE IN BAIT

As stated before, it was found that by adding water to the apples before grinding, the apples could be run through the grinder more quickly than if dry. Experiments were conducted to ascertain whether or not the more moist bait was as effective as the drier baits. From Table III it can be seen that the moist baits in every case gave just as good or better results than did the dry baits. A much greater kill was obtained with the moist bait after one night's feeding than with the drier baits.

TABLE III. EXPERIMENTS WITH APPLE BAITS OF VARYING MOISTURE CONTENT

Bait	Percent Mois- ture	Count and percentage of dead weevils at end of various periods								
		1 day			3 days			8 days		
		No. dead	No. live	Per- cent dead	No. dead	No. live	Per- cent dead	No. dead	No. live	Per- cent dead
	%			%			%			%
Calcium arsenate 5%	20	173	12	93.51	215	8	96.41	186	1	99.41
Calcium arsenate 5%	10	123	34	78.34	217	10	95.59	195	4	97.98
Sodium fluoride 5%....	15	92	58	61.33	102	48	68.00	114	37	75.49
Sodium fluoride 5%....	10	132	113	53.87	125	97	56.30	141	21	87.03
Check	X	1	331	00.30	9	386	2.27	4	180	2.17

Laboratory experiments also verified the results of the field tests. In these tests the weevils were confined in cages, in which a teaspoonful of bait was placed, and the number of weevils killed at the end of approximately each four-hour interval was counted. Apple baits containing 5 percent calcium arsenate showed the following results: baits with 1 to 5 percent moisture killed 100 percent of the weevils in 67 hours; baits with 10 to 15 percent moisture killed 100 percent of the weevils in 37 hours; and baits containing 20 to 25 percent moisture killed 100 percent of the weevils in 24 hours.

THE COMMERCIAL BAIT "GO-WEST"

The commercial bait "Go-West" was slightly less effective in our tests than the home-made baits, as can be gathered from the accompanying charts. This bait was received approximately a month before any field applications were made and no doubt dried out considerably in that time. At the time of application this bait contained from 9 to 13 percent moisture. This percentage, according to our tests with home-made baits, is not as satisfactory as a higher percentage.

Tests with this material made at Hood River by Mr. D. A. Wilbur were more satisfactory, the percent of kill averaging 63.5 percent in 24 hours, 94 percent in 4 days and 98 percent in 12 days.

TIME AND NUMBER OF APPLICATIONS OF BAIT

Theoretically, one application of bait applied at the correct time should kill all the weevils before they lay eggs. Practically, one application of bait has not as a rule proved successful and many failures with the use of bait in the 1926 season have resulted because of several factors that were not taken into consideration in the application of the bait.

The time of application of the bait (not considering other factors) varies with the species of weevil concerned. Growers who have their plantings infested with the Small Weevil and the Large Weevil are the ones to apply the bait earliest in the spring. In the lower elevations of the Willamette Valley in 1926 the bait for these two species should have been applied about May 15, which was at least three weeks before the final harvesting of the berry crop. In the Hood River Valley the application of the bait for these two species should have been made June 1. An application of the bait at this time will also control the Medium Sized Weevil, but if this is the only species in the patch the application of the bait can be made after harvest, because the eggs of this species are not laid until August.

The above dates, however, cannot be relied on year by year because the time of emergence of the weevils varies with the species of weevil, with the season, and with the locality. Judging from last season's work the correct time to apply the bait is at the time when 75 percent of the weevils have changed over to the adult stage. By digging up and examining the weevils in the soil about a plant every few days beginning in the latter part of April, the grower can determine for himself the correct time to apply the bait.

The factor largely responsible for the bait failures in 1926 was that the applications were made after harvest. Most of the adult weevils were killed by this one application but not until after they had laid a sufficient number of eggs to produce weevil larvae in great enough numbers to be highly detrimental to the plant. Examinations of such patches this fall both in the Willamette and Hood River valleys have shown in numerous cases weevil larvae averaging from 25 to 50 per hill. In other instances where the one application of bait was applied at the correct time, weevils from other sources came into the patch after the bait had lost its attraction, and laid enough eggs to produce larvae in injurious numbers.

The number of applications of bait is influenced by several factors:

(1) *The presence or absence of overwintering weevils.* No overwintering weevils were found in the lower elevations of the Willamette Valley in 1926, but were found in the Hood River and Parkdale districts. The correct time to bait and whether it is practical or not for the overwintering weevils has not been determined, as it is not known whether these weevils will eat the bait, whether they are numerous enough to warrant an application, or whether they lay a large enough number of eggs per weevil to warrant control measures.

(2) *Thoroughness of application.* The bait should be applied directly in the crown of every plant on the place whether old or young, and applications of the bait should be made to the bramble fruits or other plants found harboring the weevils. The patches should be examined at frequent intervals after the bait is applied and if any number of live weevils are found a second application of bait may be advisable. In a number of instances only the young patches were baited and old, heavily infested patches were left unbaited, thus producing a source of infestation to the young patch all summer. In other instances the old patches were plowed immediately after harvest, thus forcing the weevils to migrate to the younger patches.

(3) *Weather conditions.* Extreme weather conditions, such as heavy rains or prolonged hot, dry weather, make the bait unattractive to the weevils and the application may have to be repeated. Rain washes the poison from the bait and also makes it soggy and easily subject to mold; hot, dry weather removes the moisture.

(4) *Degree of infestation.* Where there is a heavy infestation of weevils and where weather conditions do not favor a rapid change of the weevil larvae into adults, thus spreading the emergence of the weevils over a long period of time, one or more applications of bait may be advisable following the first application.

Annual applications. It is believed that applications of bait will have to be repeated several years and that one season's application will not completely control the Strawberry Root-Weevils. The best control that was obtained in the 1926 season in a patch that was heavily infested with the Small Weevil before the bait was applied averaged 4 weevil larvae per hill in the fall of 1926. It is believed that this number of weevil larvae per hill or even twice this number would not seriously injure the plants but such a number would necessitate the baiting of the patch next season. Better results were obtained in a patch heavily infested by the Medium-Sized Weevil, the plants averaging 1/10 larvae per hill in the fall of 1926. Another factor that will make it imperative to bait several seasons is the large number of host plants of the weevils, which can support the larvae and produce a source of infestation to the strawberry plants.

METHOD OF APPLICATION

The bait is best applied to the strawberry plants by placing between a teaspoonful and a tablespoonful to each hill directly in the crown of the plant. There is no danger of contaminating the fruit by this method of application and it is more economical and slightly more effective than

broadcasting the bait along the rows. From 50 to 70 pounds of bait were used per acre when applying the bait to the crown of the plant, while more than 100 pounds per acre were necessary to get a satisfactory kill of the weevils by broadcasting along the row. Application to the crown of the plant insures an even distribution of the bait over the entire field, while by broadcasting it is impossible to distribute the bait evenly. Table IV gives the results of two experiments in which the same bait was applied on the same date by both methods of application.

TABLE IV. FIELD TESTS OF BAITS APPLIED BROADCAST ALONG THE ROWS COMPARED TO THE SAME BAIT APPLIED TO THE CROWN OF THE PLANT

Bait	Method of application	Count and percent kill of weevils at end of various periods								
		—1 day—			—3 days—			—8 days—		
		No. dead	No. live	Per-cent dead	No. dead	No. live	Per-cent dead	No. dead	No. live	Per-cent dead
Go-West	Broadcast	52	46	53.06	186	18	91.17	137	22	86.10
Go-West	In crown of plant	46	82	35.93	154	30	83.69	145	16	90.06
Calcium arsenate 5%.....	Broadcast	36	5	87.80	355	22	94.16	428	15	96.61
Calcium arsenate 5%.....	In crown of plant	66	2	97.05	336	9	97.4	309	5	98.40
Check		1	331	00.30	9	386	2.27	4	180	2.17

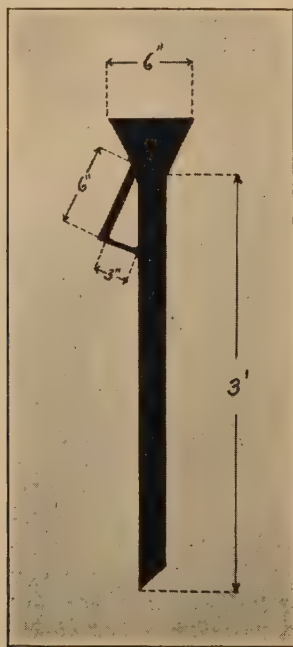


Fig. 6. Drawing of "bait gun" giving the more important measurements.

Device for applying bait to the crown of the plant. The application of the bait to the crown of the plant by hand is a very tedious and back-breaking job. To overcome this difficulty Mr. John Ramege of Woodburn and Mr. Maurice Walton of Hood River made a device termed a "bait gun" whereby the speed of application of the bait is greatly increased and the stooping and bending of the back are eliminated. This device is made from a piece of 2-inch drain pipe about 3 feet long into the top of which is soldered the top part of a 6-inch tin funnel. A handle is then fastened to the pipe just below the funnel. The bottom of the pipe is cut off at an angle of 45 degrees so that the oval opening is on



Fig. 7. Mr. John Ramege of Woodburn, applying strawberry weevil bait with "bait gun" he devised.

the opposite side from the handle. With some practice a man can apply the bait to the fields as fast as he can walk, and between 3 and 5 acres a day can be covered with a "bait gun." The main trick in using this apparatus is to drop the bait into the funnel one plant before the plant on which the bait is to be applied. At the average walking speed it takes this length of time for the bait to pass down the pipe into the crown of the plant. The bait is carried in a sack conveniently slung over the shoulder. The tinsmith in Woodburn is making and selling this device for 80c each.

EXPERIMENTS WITH BRAN BAITS

During the course of our experiments the following question came up: "What do the apples contain that makes them so attractive to the adult weevils?" After some deliberation and an examination of the various attractants used by Melander and Spuler¹ with the apple baits

it was decided that the weevils must like the apple pomace because of its high sugar content. Consequently poison-bran baits were made up according to the following formula and field and laboratory tests with this material were made:

Bran	5 pounds
Molasses	1 pint
or sugar	1 pound
Poison	4 ounces
Water	2 quarts

The results of the laboratory experiments with these materials were very gratifying: 100 percent kill was obtained in from 12 to 23 hours with each of the following poisons—zinc arsenate, calcium arsenate, sodium fluoride, magnesium arsenate, and sodium fluosilicate. Two species, the Small and Medium-sized Weevils, were used in these tests.

The field tests were conducted in the planting infested with the Medium-sized Weevil and the bait was applied to the crown of the plants. The results of these experiments are shown in Tables V and VI. At the time of checking the experiments the bran baits had thoroughly dried and apparently were no longer attractive to the weevils. As can be seen from the tables, the results of the tests with poison bran baits compare somewhat favorably with the apple bait tests applied and checked on the same date. The problem now is to make additional tests with the poison bran baits so as to ascertain their efficiency under varied conditions and to change their physical property so that they will remain attractive to the weevils for a longer period of time.

TABLE V. FIELD TESTS OF POISON BRAN BAITS COMPARED WITH THE COMMERCIAL BAIT GO-WEST

Plot No.	Bait used	Count and percentage of dead weevils at end of 7 days		
		No. dead	No. live	Percent dead
1	Sodium fluosilicate—molasses	22	10	68.75
2	Magnesium arsenate—molasses	11	13	45.83
3	Zinc arsenite—molasses	63	8	88.73
4	Calcium arsenate—molasses	46	8	85.18
5	Lead arsenate—molasses	58	18	76.31
6	Magnesium arsenate—sugar	12	22	35.29
7	Zinc arsenite—sugar	26	11	70.27
8	Calcium arsenate—sugar	62	4	93.93
9	Sodium fluosilicate—sugar	49	29	62.82
10	Go-West	64	11	85.33
X	Check	0	55	00.00

TABLE VI. FIELD TESTS OF POISON BRAN BAITS CONTAINING DOUBLE STRENGTH MOLASSES* COMPARED WITH HOME-MADE APPLE BAITS

Plot No.	Bait used	Number and percentage of dead weevils at end of 4 days		
		No. dead	No. live	Percent dead
1	Magnesium arsenate 5%—molasses	93	16	85.32
2	Zinc arsenite 5%—molasses	100	18	84.74
3	Calcium arsenate 5%—molasses	57	5	91.93
4	Sodium fluosilicate 5%—molasses	51	19	72.85
5	Calcium arsenate 5%—apple	92	7	92.92
6	Zinc arsenite 5%—apple	106	11	90.59
7	Magnesium arsenate 5%—apple	59	9	86.76
X	Check	0	55	00.00

*Twice as much molasses as given in formula.

EXPERIMENTS WITH DUSTS

In preliminary laboratory experiments it was demonstrated that the weevils can be killed by poison dusts. The manner of ingesting the poison is not so much in that the weevils eat the poisoned leaves, but that in walking through the dust they get the poison on the end of their beaks and ingest it in this manner. The dusting experiment reported below was conducted in the field infested by the Medium-sized Weevil. The first application was made June 8, 1926 and was made only to a single row of plants with untreated plants on either side. As the weevils moved from the undusted to the dusted rows and vice versa each evening, our counts made after the first application were consequently decidedly in favor of the live weevils. A second application was made to the single row and to the adjacent rows on June 24 and the results recorded at the end of 8 or 14 days after the second application. The

TABLE VII. EXPERIMENTS WITH POISON DUSTS FOR THE CONTROL OF THE MEDIUM-SIZED STRAWBERRY ROOT-WEEVIL, *B. RUGIFRONS* GYLL.*

No.	Dust used	Count and percentage of dead weevils at end of various periods											
		—2 days—			—7 days—			—24 (8)* days—			30 (14)* days		
		No. dead	No. live	Per- cent dead	No. dead	No. live	Per- cent dead	No. dead	No. live	Per- cent dead	No. dead	No. live	Per- cent dead
				%			%			%			%
1	Sodium fluosilicate	54	81	40	168	132	56.00	213	18	92.29	239	6	97.55
2	Calcium arsenate 50%†	78	145	34.95	105	244	30.08	161	20	88.95	234	16	93.60
3	Sodium fluoride 50%	14	147	8.69	46	158	22.55	-----	-----	-----	-----	-----	-----
4	Lead arsenate 50%	15	146	9.33	125	75	62.50	187	18	91.21	196	18	91.58
5	Calcium fluosili- cate	49	79	38.28	165	124	57.09	242	76	76.10	308	31	90.85
X	Check	1	99	1.00	4	96	4.00	0	84	0.00	0	55	0.00

*Number in parentheses indicates periods after second application.

†In dusts Nos. 2, 3, and 4 an equal amount of poison was mixed with an equal amount of hydrated lime.

results of this experiment are reported in Table VII. It will be noted that the percentage of kill 8 and 14 days after the second application was made compares favorably with some of the bait tests. Additional tests with dust materials are planned for the coming season on a much larger scale so that the exact status of this method of control for the Strawberry Root-Weevils can be ascertained.

LIFE-HISTORY AND HABITS OF THE WEEVILS

It is important that the grower be familiar with the life-history and habits of the weevils. As can be gathered from the preceding discussion, successful control depends on whether or not the weevils are killed in the spring before they lay their eggs. In order to aid the grower to recognize the various stages of the weevils and understand the life-history, these facts are given in as brief a form as possible with illustrations.

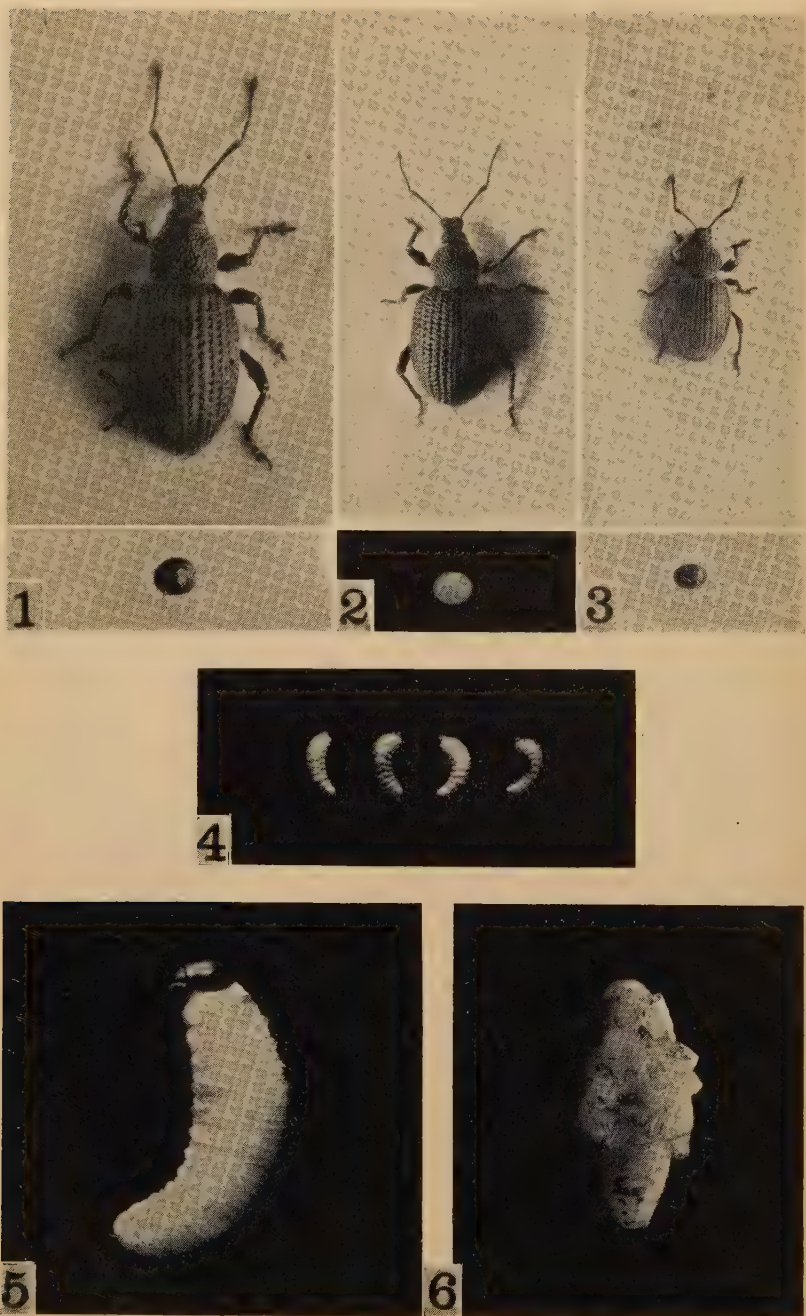


PLATE I. 1. Adult and egg of the Large Weevil *B. sulcatus* (3X).
 2. Adult and egg of the Medium-sized Weevil *B. rugifrons* (3X).
 3. Adult and egg of the Small Weevil *B. ovalis* (3X).
 4. Strawberry root-weevil larvae, natural size.
 5. Larva or grub of Strawberry Root-Weevil (4X).
 6. Pupa of Strawberry Root-Weevil (4X).

Adult weevils. (See Plate I, 1, 2, 3.) The adult weevils are dark brown in color and vary from $3/16$ to nearly $5/8$ inch long. The Small Strawberry Root-Weevil averages $3/16$ inch in length; the Medium-sized Weevil $5/16$ inch in length; and the Large Weevil $7/16$ inch in length. They possess the characteristic weevil snout. This character, together with the dark-brown color, the comparatively big, rough, oval abdomen, and the much smaller thorax and head will serve to distinguish the strawberry weevils from other insects found about the plants.

The time of emergence of the weevils varies in the spring from May 1 to June 15. The Small Strawberry Root-Weevil is the first to change over in the spring, and is followed in about a week's time by the Large Weevil and in two week's time by the Medium-sized Weevil. They feed for about two weeks on the strawberry leaves before they begin to lay fertile eggs. Activity takes place only at night. During the day time they remain hidden down in the crown and under dead leaves and clods of earth about the base of the plants. The weevils when found appear as though dead; they draw their legs close to their bodies and "play possum."

Eggs. (See Plate I, 1, 2, 3.) The eggs are usually laid singly or in groups of from 2 to 7 in and about the crown of the plant, on the soil and on the dead leaves. They are pearly white when laid but soon change to an amber color. The size and shape of the eggs varies with the species: those of the Small Weevil are oval and .0157 inch wide by .0197 inch long (.4 x .5 mm.); those of the Medium-sized Weevil are ovoid and .0197 inch wide by .0216 inch long (.5 x .55 mm.); and those of the Large Weevil are nearly spherical and .0236 inch (.6 mm.) in diameter. The Small and Large weevils lay their eggs principally in June and July, and the Medium-sized Weevil in August. The majority hatch in from one to three weeks.

Larvae. (See Plate I, 4, 5.) The larvae or grubs are white, legless, and have a light brown head. They are found mainly about the smaller roots of the plant in the ground from 1 to 10 inches deep. A great number of the grubs attain their full growth by fall and pass the winter practically full grown. Feeding is continued in the spring but only for a short time before pupation takes place. The grubs when full grown measure as follows: the Small Weevil $\frac{1}{4}$ inch long, the Medium-sized Weevil $\frac{3}{8}$ inch long; and the Large Weevil $\frac{1}{2}$ inch long. The larval stage of the weevil lasts from July to May or a period of about 10 months.

Pupae. (See Plate I, 6.) The larvae change to pupae in the soil in small oval, earthen chambers which they prepare. The pupae are white in color and are characterized by the various appendages and body parts of the adult weevil. This stage averages in length about three weeks before the adult weevil is formed. Pupation takes place during April and May.

Seasonal history of the three species of weevils is thus seen to be quite similar, varying only in the more minute details. One generation of adult weevils is produced each year. The winter is passed as grubs in the soil about the roots of the strawberry plants. In the spring, April and May, the grubs pupate and change over to adult weevils. The adult weevils begin to appear at practically the same time that the harvesting

of the berry crop takes place. Egg laying takes place in the summer. The seasonal history is sometimes complicated by the fact that some of the adult weevils overwinter, coming out early in the spring and laying a few eggs.

CULTURAL MEASURES AS AN AID IN CONTROL

Although applications of poison baits show promise of giving good control of the Strawberry Root-Weevils, cultural practices that aid in their control are not to be neglected. Good farm practices such as the selection of good vigorous plants and the use of fertilizers and cover crops in a systematic crop rotation are important. By keeping the plants in a vigorous growing condition, the grower is not only assured a better return in berries but the plants are more able to withstand the attacks of the weevils and other insects.

Clean cultivation in and near the strawberry planting cannot be too strongly emphasized as a number of grasses and weeds are able to support the weevil larvae, thus producing a source of infestation to the berry plantings each year. The time of plowing up old fields is also important and is accomplished to the best advantage in the fall. Plowing the fields in the summer or after harvest drives the weevils from the older fields into the younger plantings, thus making them more difficult to control. Plowing old plantings in the fall, destroying the plants, and keeping the planting free of weeds until the following spring serves to starve out the larvae that are there and also to expose them to adverse weather conditions. Destroying the plants in the fall also aids materially in the control of the strawberry crown-borer and crown miner.

ACKNOWLEDGEMENTS

The writers are indebted to Mr. Donald A. Wilbur, who conducted the experiments in the Hood River district, and to Mr. Earl G. Davis and Mr. Sidney C. Jones, who assisted with the field and laboratory experiments in the Willamette Valley and at the Experiment Station in Corvallis. The writers also express their appreciation to Mr. Ray Glatt, Mr. John Ramege, and Mr. John Susee and to others of the Woodburn Co-operative Fruit Growers Association, to the Hood River Apple Growers Association, and to Mr. Joe Perry of Shaw, who all generously gave us their time, strawberry patches and assistance and in a big measure by their cooperation made the tests with the weevil baits successful. The cooperation and aid offered to Mr. Wilbur by Mr. Leroy Childs, Mr. C. C. Walton, and others in the Hood River and Parkdale districts are also greatly appreciated.

SUMMARY

Four species of weevils have been found feeding on and destroying the roots and crown of the strawberry plants in Oregon. Only three of these species are discussed in this circular.

The weevil larvae either kill or devitalize the plants by feeding on the roots. Infested fields usually show distinct spotted areas in which the plants are stunted.

The distribution of the weevils in Oregon includes practically all of the commercial berry producing sections of the state.

The cultivated host plants that the grubs feed on are strawberry, raspberry, blackberry, loganberry, cranberry, and also a number of grasses and weeds.

Experiments made during the 1926 season have shown that the adult weevils can be killed by a bait made of 95 pounds of ground dried apple waste mixed with 5 pounds of powdered poison.

Apple waste or pomace is used to make the bait. This is ground through a meat grinder and then mixed with poison.

Calcium arsenate was the poison found to be the most effective in the tests and is the one recommended for use.

Five percent poison, or 5 pounds of poison to 95 pounds of ground apple pomace, is recommended.

Baits containing from 20 to 25 percent moisture were as effective as baits containing less percentage of moisture.

The commercial bait "Go-West" was not quite as effective as the home-made baits in the tests in the Willamette Valley, but was as effective in the tests made in the Hood River Valley.

The time of application of the bait varies with the species of weevil, the locality, and the season. In 1926 the bait for the Small Weevil and the Large Weevil in the Willamette Valley should have been applied about May 15, and in the Hood River Valley about June 1. The bait for the Medium-sized Weevil may be applied at the above times but can be delayed until after the berries are harvested. The grower can determine for himself the correct time to apply the bait by making frequent observations of the weevils in the spring.

The tests of last season indicate that the time to make the first application of the bait is when approximately 75 percent of the weevils have changed to the adult stage. The number of applications that are necessary to obtain good control of the weevils varies with individual conditions.

The bait is applied at the rate of from 50 to 70 pounds per acre. Between a teaspoonful and a tablespoonful of bait is applied with a device termed a "bait gun," directly into the crown of each plant.

Experiments with poison-bran baits and poison dusts show promise of being practical measures for the control of the Strawberry Root-Weevils. The exact status of these control measures will have to be determined by future experiments.

The life-history of the three weevils is quite similar. One generation of adult weevils is produced each year. The winter is passed as larvae or grubs in the soil about the roots of the strawberry plant. In the spring, the larvae pupate and change over to adult weevils, which come out of the ground and feed on the leaves of the plants. Eggs are laid during the summer in and about the crown of the plant. The seasonal history is sometimes complicated by the fact that some of the adult weevils overwinter and come out early in the spring and lay a few eggs.

Good farm practices, such as the selection of good, vigorous plants, the use of proper fertilizers and cover crops, the time of plowing of old patches, and the use of a systematic crop rotation, are important in helping to combat the weevils.

LITERATURE CITED

- ¹Melander, A. L. and Spuler, A. Poisoned Baits for Strawberry Root-Weevil. Wash. Agri. Exp. Sta. Bul. 199. 1926.
- ²Downes, W. The Strawberry Root-Weevil. Dominion of Canada Dept. of Agri. Pamphlet No. 5—New Series. 1924.
- ³Lovett, A. L. The Strawberry Root-Weevil. 16th Annual Report of the Board of Horticulture; State of Oregon, 1921.
- ⁴Lovett, A. L. The Strawberry Root-Weevil. Ore. Bien. Crop Pest and Hort. Rept. 1913.